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THE POSSIBILITY OF OBTAINING VERY HIGH PRESSURES BY A THERMAL METHOD

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Investigations requiring very high pressures (several thousands of atmospheres) are often hindered because of the need for high-pressure generators which are usually quite complex in construction (L. F. Vereshchagin, ZhTF, XVI, 669, 1946). These generators can be built only where there are well-equipped mechanical shops with qualified personnel. Even if a generator is obtained despite its high cost, a qualified mechanic is often needed for maintenance. The main advantage of these generators, i.e., the possibility of creating pressures in arbitrarily large spaces in a comparatively short time and of maintaining this pressure even when leakage is present, cannot always be utilized -- in biological, chemical, and many physical investigations, for example, which are carried out in small closed spaces. Moreover, pressure pulses, which are unavoidable in the operation of these generators (the more so, the smaller the working space), may actually be dangerous in a number of cases.

At the same time, it is easy to build units in which pressures above 5,000 atmospheres can be obtained in spaces of several centiliters by very primitive methods. Moreover, pressure can be applied and removed smoothly and at any speed, from several atmospheres to several hundred and even thousands of atmospheres per minute. Simon, Ruheman, and Edwards (ZS Phys. Chem., 6, 331, 1930) and Rudenko and Elunitsyn (ZhETF, 16, 776, 1946) used a multistage unit based upon the thermal expansion of gas to create high gas pressures. Lazarev and L. Kan obtained pressures above 1,500 atmospheres at temperatures of liquid helium by the use of water freezing in a closed space (ZhETF, 14, 439, 1944). The pressure increase that results from heating and fusion of a substance at constant volume can be used to obtain very high pressures in a liquid at room and higher temperatures.

By using data on compressibility, coefficient of thermal expansion, and increase of volume in fusion, it is easy to calculate the pressure that will be obtained by this method if ethyl alcohol, for example, is used as the working

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fluid. Ethyl alcohol decreases in volume 15.5 percent when cooled to the solidification point, minus 117 degrees centigrade. Moreover, in freezing, the volume decreases 3.5 percent more, with respect to the volume at 20 degrees centigrade. Thus, frozen alcohol occupies 81 percent of the volume held at 20 degrees centigrade and atmospheric pressure (Bridgman, Proc. Am. Arts and Sc., 75, 399, 1942). Consequently, if alcohol frozen under atmospheric pressure is heated in a closed vessel to 20 degrees centigrade, it will develop the pressure necessary to decrease its volume by 19 percent at this temperature. This pressure exceeds 6,000 atmospheres (P. V. Bridgman, Physics of High Pressures).

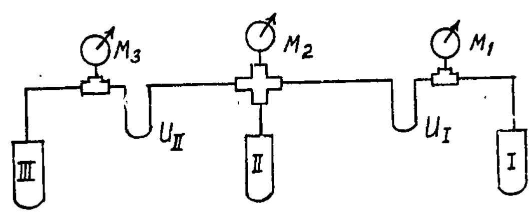
A similar calculation for the second cycle, in which alcohol is frozen at 5,000 atmospheres pressure, shows that this will yield pressures above 10,000 atmospheres, i.e., the limit set by the strength of single-layer vessels.

When mercury is used as the working fluid, pressures above 12,000 atmospheres at room temperature can, in principle, be obtained in one step. This is very difficult in practice, however, since mercury corrodes steel (P. V. Bridgman, op. cit.). The author once obtained a pressure which exceeded 20,000 atmospheres, judging by indirect signs, by using mercury at 150 degrees centigrade. Unfortunately, the vessel was destroyed by this pressure.

A unit (see appended sketch) was assembled to check the calculations cited above. Cylinder III is the reactor and is filled with the liquid called for by the conditions of the experiment. Cylinder II, the generator, is filled with a liquid having a low freezing point (alcohol, pentane, light gasoline). This same liquid also fills all connecting tubes and manometers. Cylinder I, which is isolated from the unit, is also filled with a liquid having a low freezing point and cooled so that the liquid frozen in it fills it to the stopper. It is screwed into the unit in this state and heated to as high a temperature as possible, in boiling water, for example, with the speed permitted by the conditions of the experiment. Since Cylinder I is an auxiliary, it must have as high a capacity as possible, which can be most easily obtained by decreasing the thickness of the walls and consequently the maximum pressure which can be developed in this cylinder.

When the pressure in the entire system reaches this value, the maximum pressure in Cylinder I, cooling of Cylinder II must be started while heating of Cylinder I is continued so that the pressure will remain constant throughout the system. When all the liquid in Cylinder II is frozen, Cylinder I is disconnected from the unit by freezing the capillary U_I, and Cylinder II is heated to the maximum permissible temperature. If the pressure thus developed is not high enough, still higher pressure can be obtained in the reactor by repeated heating of Cylinder II after having frozen capillary U_{II}, again by cooling Cylinder II and driving over a slightly additional amount of working fluid into it from Cylinder I. In this unit, we easily obtained in one step a pressure of 3,500 atmospheres, despite the fact that the connecting tubes and manometers presented a large danger area and Cylinder I did not admit of initial pressures above 1,000 atmospheres.

[Appended sketch follows.]



A diagram showing the set-up for obtaining very-high pressures by a thermal method.

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